



*NASA Support for the Future  
Communications Study*

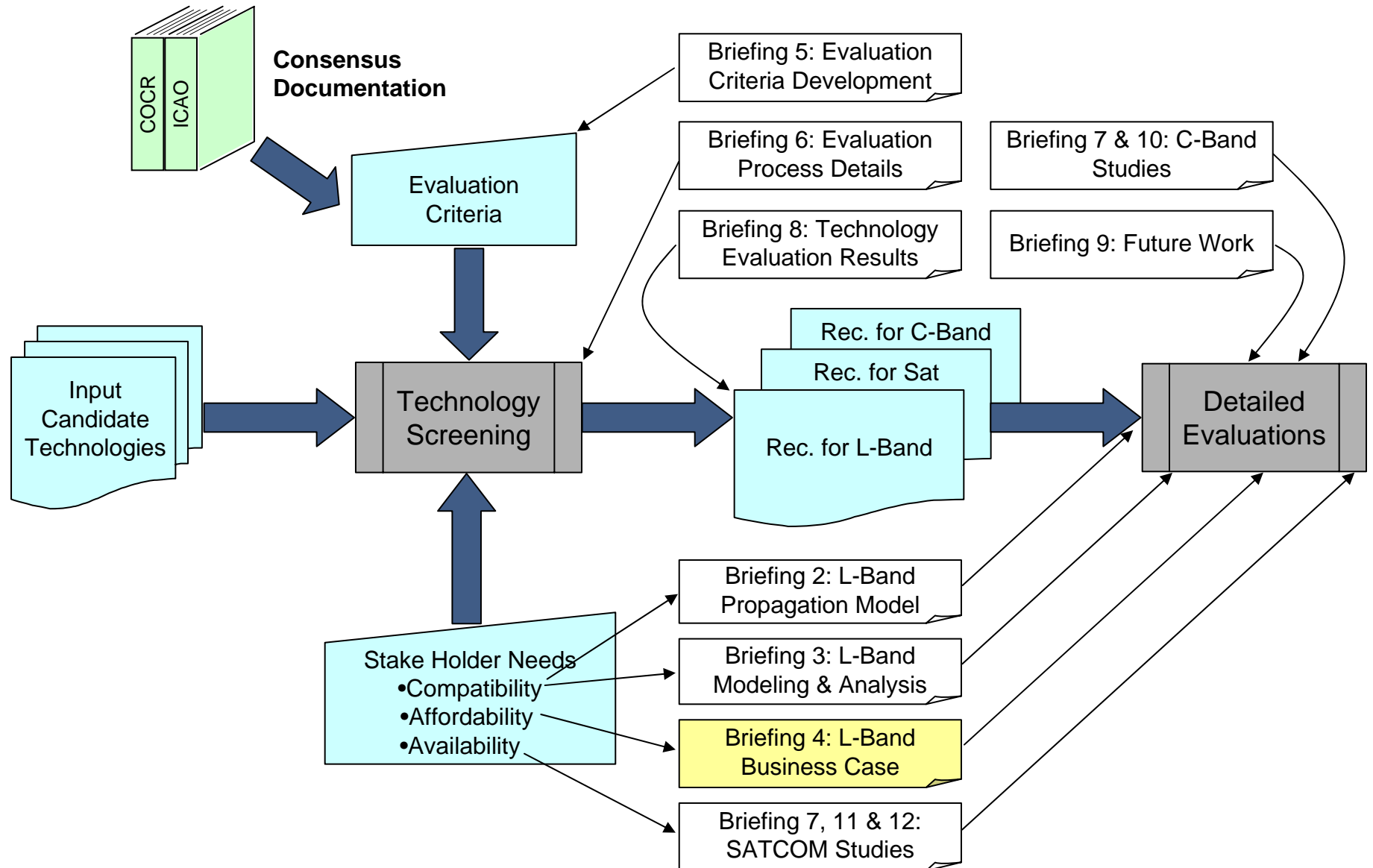
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***Briefing #4 - L-Band Business Case  
Analysis***

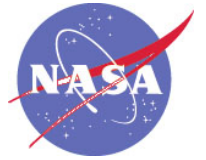
Future Communications Study  
Phase II End of Task Briefing

June 21, 2006



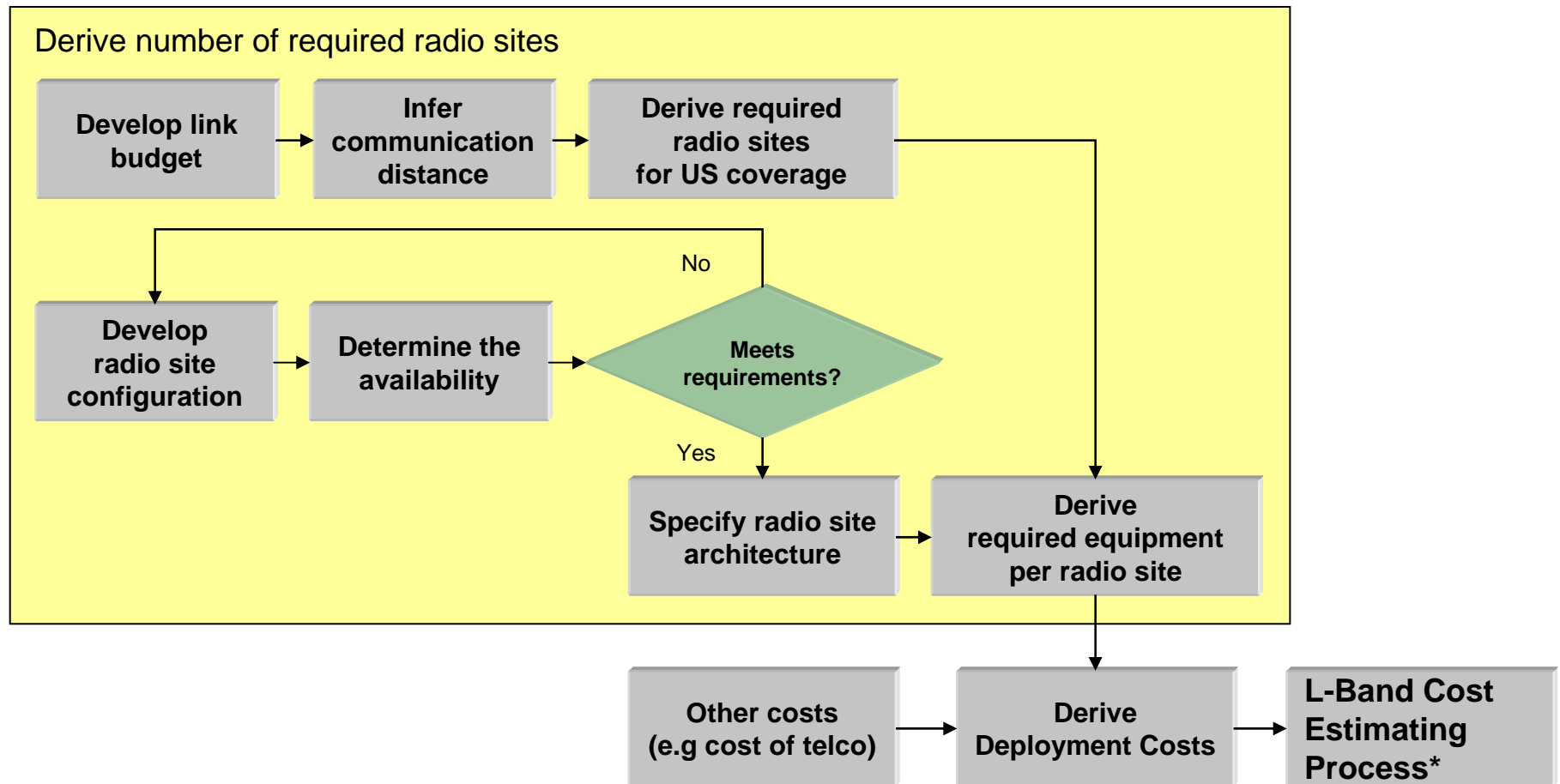


# *Background & Objective*

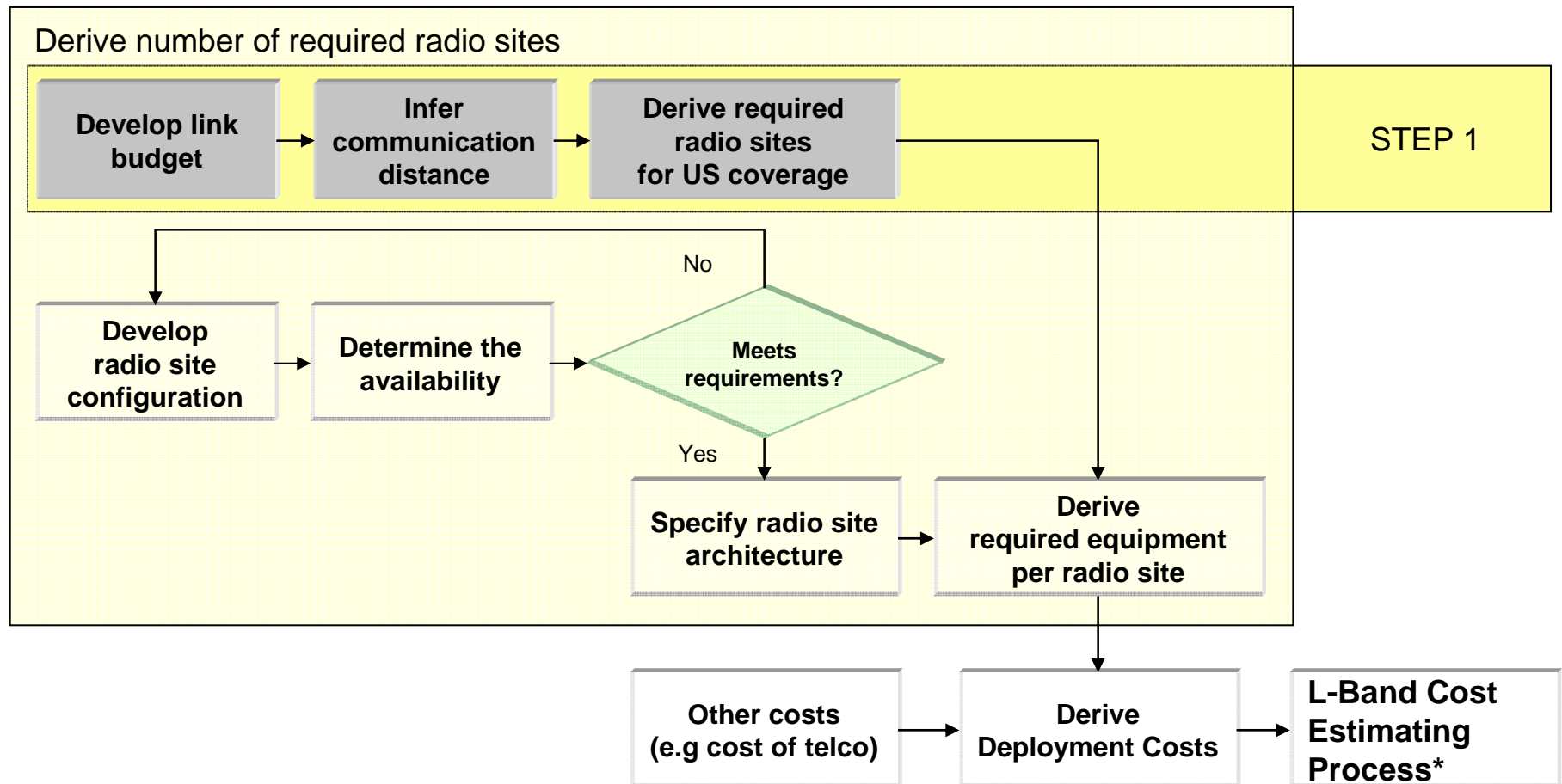


- Future FAA policy might be shifting towards leasing of infrastructure as opposed to ownership of assets
  - As currently developed, the NAS is a massive infrastructure with correspondingly massive Operations and Maintenance (O&M) costs
  - Additional ground infrastructure; however functional or necessary, may simply not be affordable
    - Development of an Air-ground data communications network at L-Band might never be accomplished by the FAA due to financial constraints
  - Commercial deployment of this infrastructure, if encouraged and subsidized by the FAA will require a business case showing expedient returns on initial investments and associated O&M costs
- The objective of the Business Case Development task is to determine if the business case can close. The process for accomplishing this objective is:
  - Through detailed analysis, develop a notional ground L-Band architecture that can meet Future Communication Infrastructure (FCI) requirements as defined in the Communications Operating Concept and Requirements for the Future Radio System (COCR) document for ATC communications
  - Develop cost elements and estimates for initial development and O&M
  - Determine required revenue flow to close business case

- Through detailed analysis, develop a notional ground L-Band architecture that can meet Future Communication Infrastructure (FCI) requirements as defined in the COCR for ATC communications
  - Derive number of radio sites required for total US coverage
    - Perform L-Band link budget analysis
      - Develop L-Band Link budget spreadsheet and derive the parameters to close the link
      - Excess Path Loss derivation
    - Perform L-Band coverage analysis
    - Derive radio site redundancy to meet system availability requirements
      - Develop an architecture to meet availability required
- Determine if the business case can close
  - Develop cost elements and estimates for initial development and O&M
  - Determine required revenue flow to close business case



\* The L-Band cost estimating process is described in detail later in the presentation



\* The L-Band cost estimating process is described in detail later in the presentation

- Link budget is the calculation required to assess the actual system performance in a particular application (in our case, L-Band)
- System technical parameters dictate the coverage area that a radio site can provide at any given time.
  - System technical parameters include three major components
    - Link Powers
      - Transmit Power
      - Noise Power
    - Link Gains
      - Antenna gains
      - Additional gains (e.g. diversity reception, special coding, or array processing)
    - Link Losses
      - Transmission-line losses
      - Propagation loss
      - Shadowing/fade margin (excess path loss)
      - Implementation losses (both in the transmitter and the receiver)

- Many of the link budget technical parameters are technology dependent (data rate and modulation type, which drives required  $E_b/N_0$  are examples of this)
  - To leverage prior studies, the underlying technology for this analysis is the “L-Band Data Link”
  - Several resources exist that describe this technology and suggest values to be used in link budget calculations
    - Dr. Wilson, W., June 2005, "An L-Band Digital Communications Link Concept for Air Traffic Control" The MITRE Corporation, McLean Virginia (MP05B0000018)
    - RTCA, Inc. DO-224B, August 3 2005, “Signal In Space Minimum Aviation System Performance Standards (MASPS) For Advanced VHF Digital Data Communications Including Compatibility With Digital Voice Techniques” (Appendix L Preparation of Link Budgets for VHF Data Link)
    - RTCA, Inc. DO-282A, July 29 2004, “Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast (ADS-B)”

- References on the previous slide were used to develop the Link Budget presented below, which can be used to derive communications coverage
  - Link Budget (shown below) closes at 160nmi

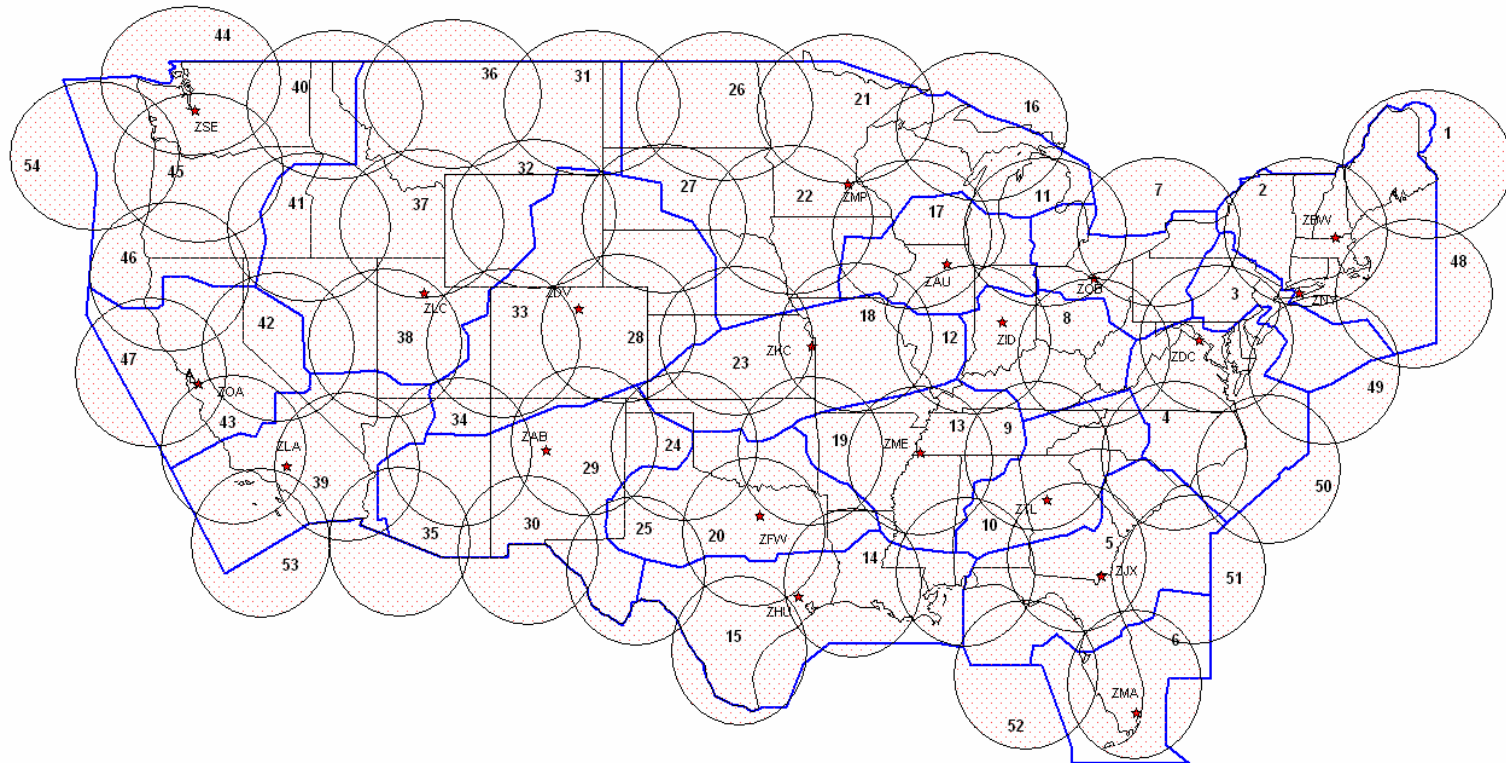
v05	<b>L-Band link budget</b>	<i>L-Band link budget Gr = 6.0dBi</i>
1	Slant Range (nmi)	160.0
2	Ground Antenna Height (ft)	50.0
3	Frequency (MHz)	1024.0
4	Transmitter Power (watts)	25.0
5	Transmitter Power (dBm)	44.0
6	Transmit Antenna Gain (dBi)	-4.0
7	Transmit Line Losses (dB)	3.0
8	Transmit EIRP (dBm)	37.0
9	Free Space Loss (dB)	142.1
10	Excess Path Loss (dB)	4.0
11	Receive Antenna Gain (dBi)	6.0
12	Receiver Line Loss (dB)	2.0
13	Receiver Signal Level (dBm)	-105.1
14	Receiver Noise Figure (dB)	5.3
15	Receiver Noise Power Density (dBm/Hz)	-168.7
16	Total System Noise Power in specified Data Rate (dBm)	-118.7
17	Data Rate (kHz)	100.0
18	Theory Es/No for a BER of 0.001	9.0
19	Raised Cosine Filter Loss (dB)	1.8
20	Transmitter Implementation Loss (dB)	1.0
21	Receiver Implementation Loss (dB)	1.2
22	Required Es/No (dB)	13.0
23	Required Receiver Sensitivity (dBm)	-105.7
24	Es/No Availabale (dB)	13.6
25	Residual System Margin (dB)	0.6

Calculated from statistics derived from multiple iterations of the IF-77 Electromagnetic Wave Propagation Model (Gierhart-Johnson) model for slightly rolling plains terrain

The LDL description document proposes several data rates for LDL. 100 kHz was selected based on analysis of capacity requirements in US in the 2020 – 2025 time frame

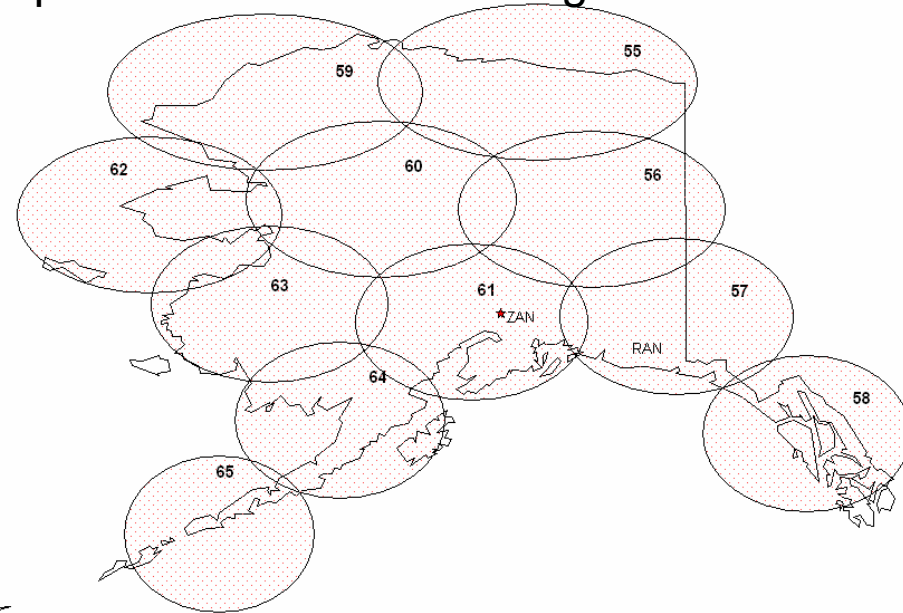
# *Derive Required Radio Sites for US Coverage*

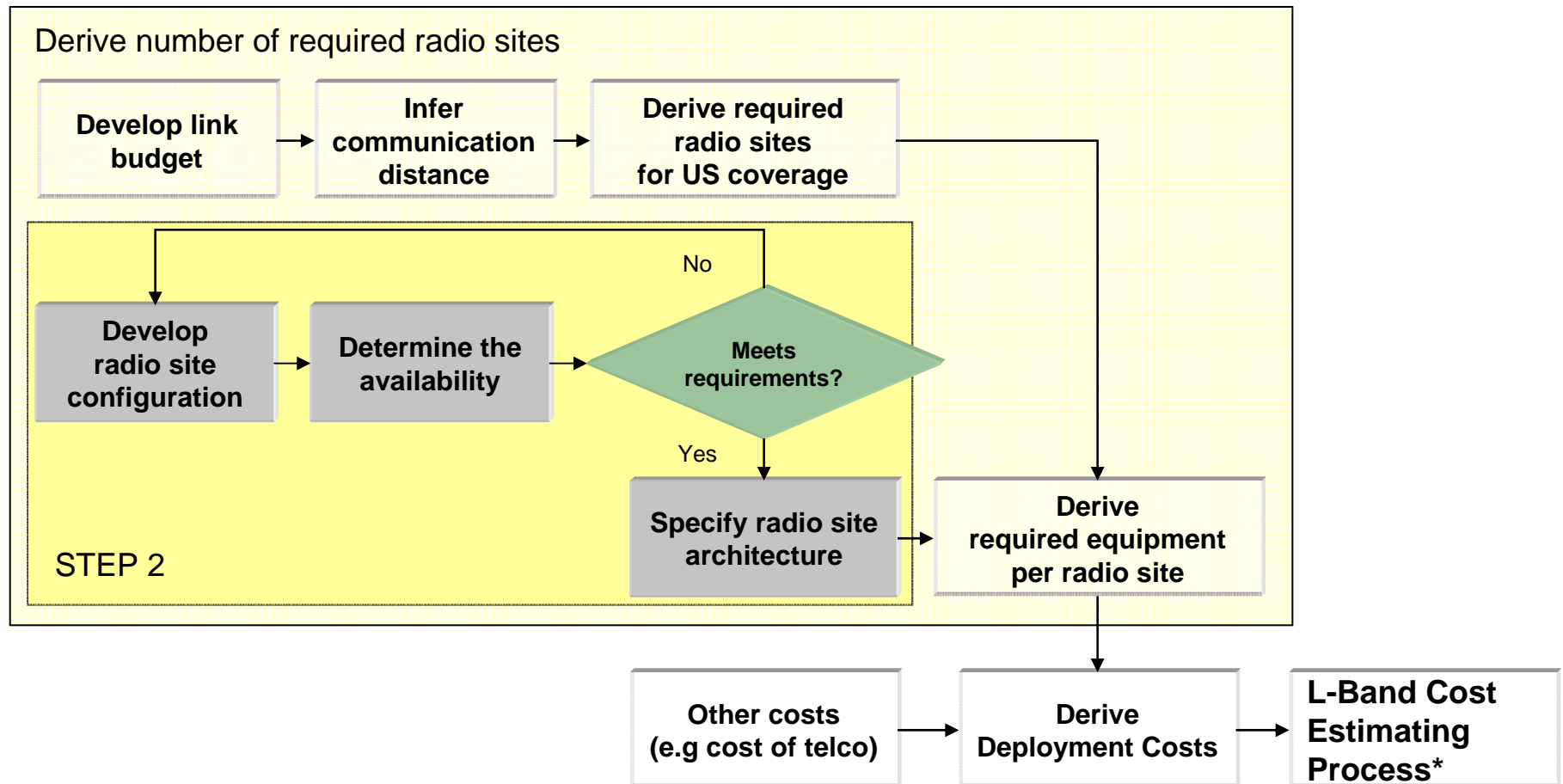
- Using the link budget developed slant range distance (160 nmi), develop a “lay down” for radio coverage in a region of interest
  - A notional radio placement to provide complete coverage above FL180 is shown



# *Derive Required Radio Sites for US Coverage (2)*

- Develop a “lay down” for radio coverage in a region of interest
  - A notional radio placement to provide complete Alaska and Hawaii coverage
  - A total of 66 radio sites are required for total US coverage

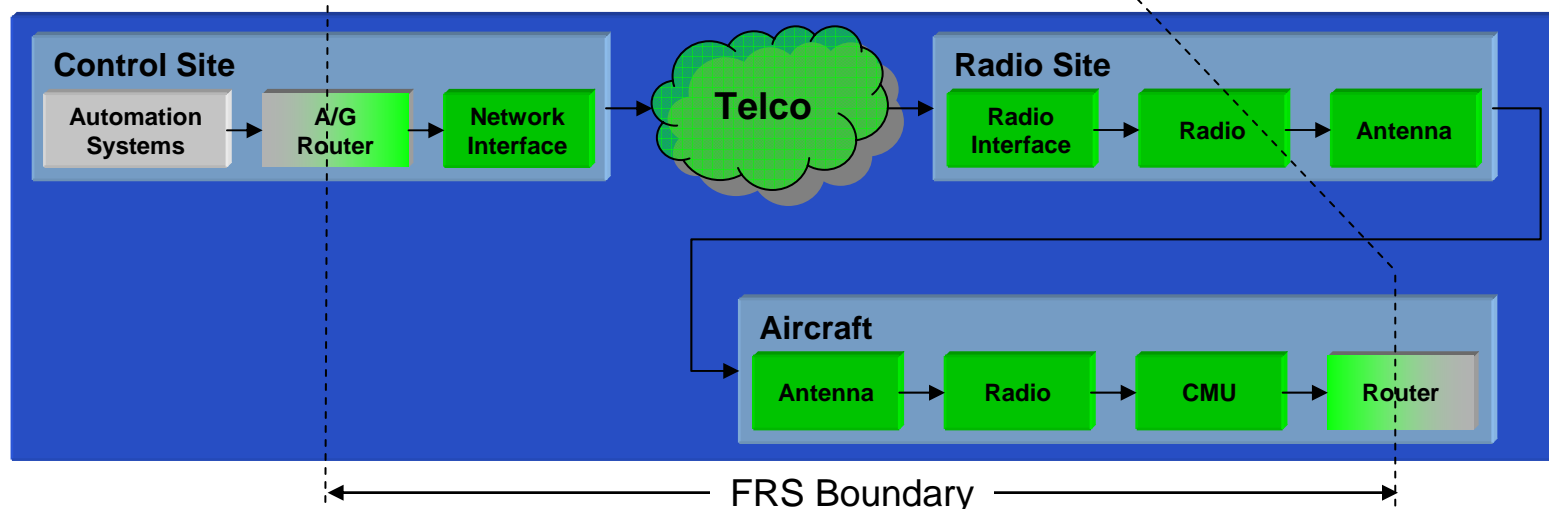
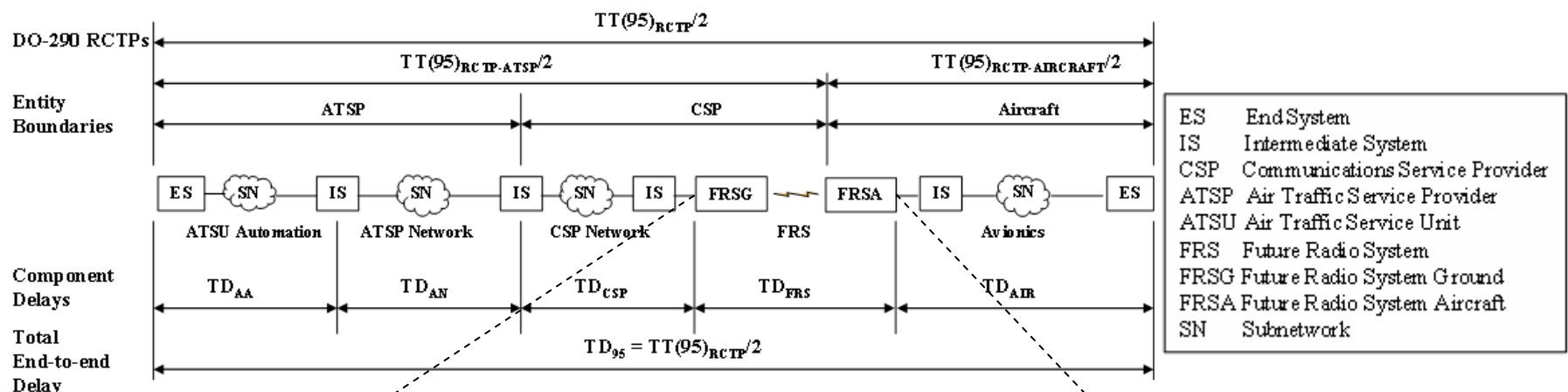




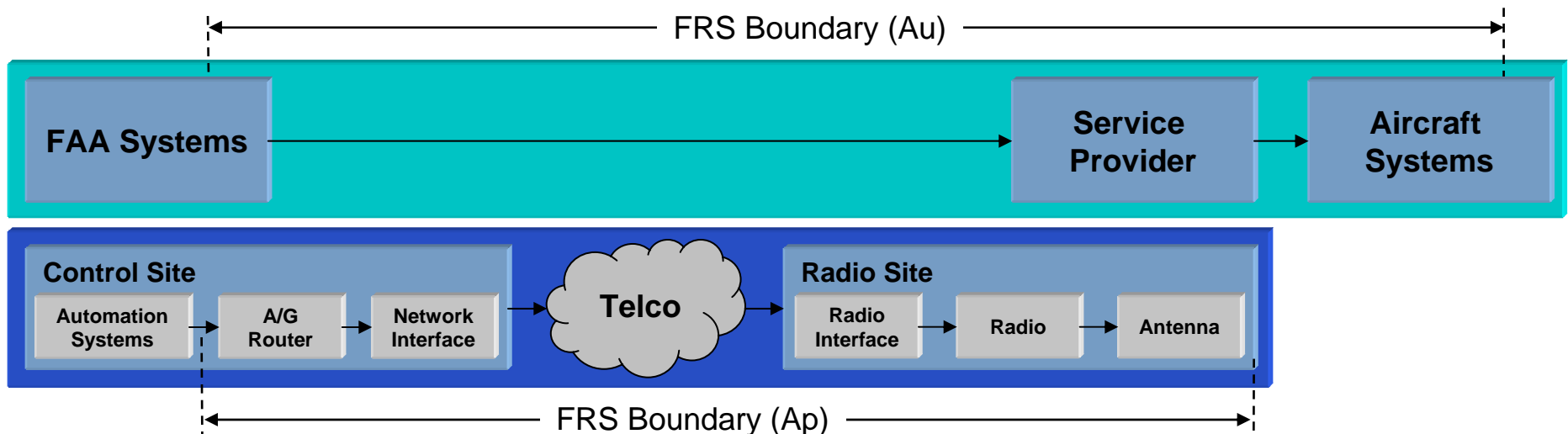
\* The L-Band cost estimating process is described in detail later in the presentation

- The COCR specifies the FRS availability requirements in two ways, “availability of use” and “availability of provision” (definitions, adapted from DO-264, are provided below)
  - Availability of Use
    - Availability of use is the probability that the communication system between the two parties is in service when it is needed
  - Availability of Provision
    - Availability of provision is the probability associate with loss of service to all aircraft in the area
- COCR Availability requirements apply to certain boundary points (discussion to follow)
- COCR availability requirements are defined by Operational Services, are mapped into Classes of Service, and are assigned by FRS phase (I or II) and by flight domain
  - Phase I En-route requirements are 0.9995. Phase II En-route requirements are 0.99999995. We assess several architectures and arrive at a candidate architecture that comes close to the Phase II required availability of provision (Ap requirements are most stringent)

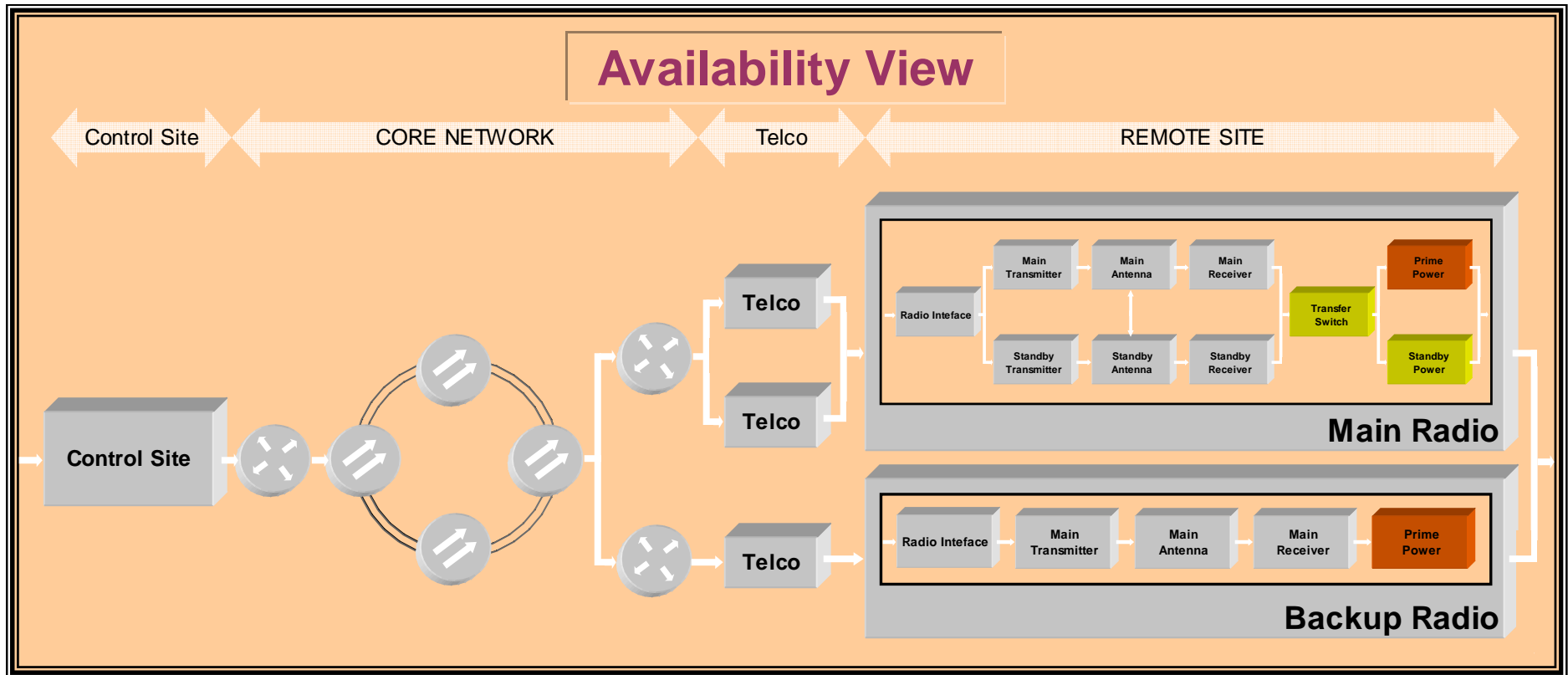
- The boundary of the FRS is defined as the interface to a Subnet Dependant Conversion Facility (SND CF), a logical rather than physical boundary point
  - Corresponds to architecture elements shown
  - Not all elements are necessary components of “availability of provision” model



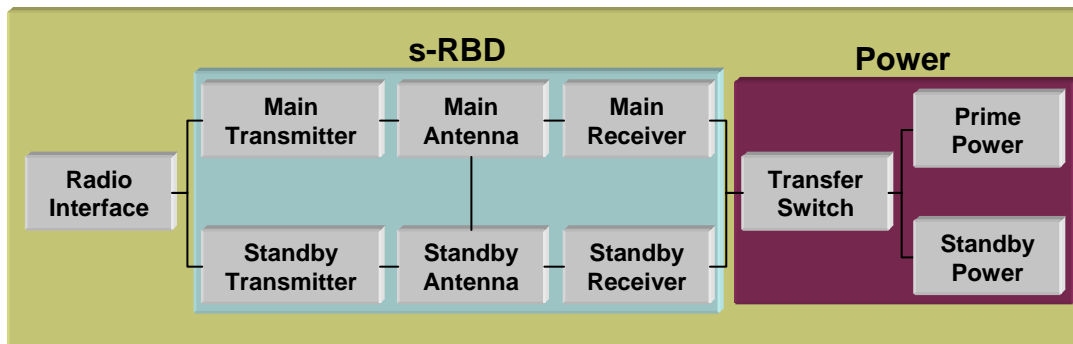
- From the definitions, the two availability requirements are against different sets of equipment
  - Arguable point; however, it is inconceivable that ALL of the aircraft systems could simultaneously fail
  - Hence, from an Ap standpoint, the availability of the aircraft systems is one
  - Diagram shows the availability extent for the two availability definitions



- Radio site architecture and availability
  - Used the method of progressive expansion to calculate the availability of radio site configuration . The following radio site configuration can achieve inherent availability of  $\sim .9999799$



- Calculate the availability of different radio site configurations
  - Several radio configurations were examined in order to closely meet availability requirements with the main goal of maintaining architecture cost at reasonable level.
  - “NEXCOM Reliability, Maintainability, and Availability (RMA)” and “Next Generation Air/Ground Communications” documents were the main sources for
    - Approach used to calculate the radio site availability
    - Configuration parameters values

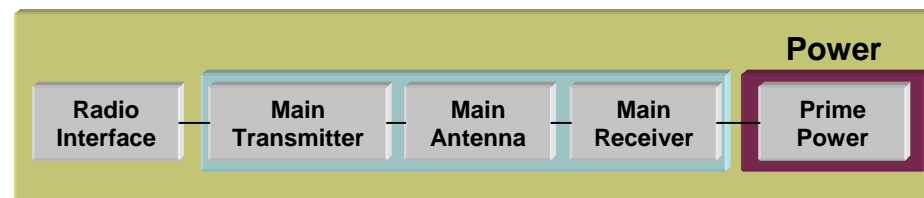


Main Radio Configuration

For a detailed description of s-RBD availability derivation see “Next Generation Air/Ground Communications, v1.0, 2002” document

RMA Analysis	MTBF (hrs)	MTTR (hrs)	Availability
Radio Interface	40000	0.5	0.999987500
s-RBD			0.999999999
Power			0.999996925
<b>Main Radio Configuration</b>			<b>0.999984425</b>
Main Tx	52560	0.5	0.99999049
Main Ant.	52560	0.5	0.99999049
Main Rx	52560	0.5	0.99999049
Standby Tx	52560	0.5	0.99999049
Standby Ant.	52560	0.5	0.99999049
Standby Rx	52560	0.5	0.99999049
<b>s-RBD</b>			<b>0.999999999</b>
Prime Power	5662	0.5	0.9999117
Standby Power	52560	0.5	0.999990487
Transfer Switch	162666	0.5	0.999996926
<b>Power</b>			<b>0.999996925</b>

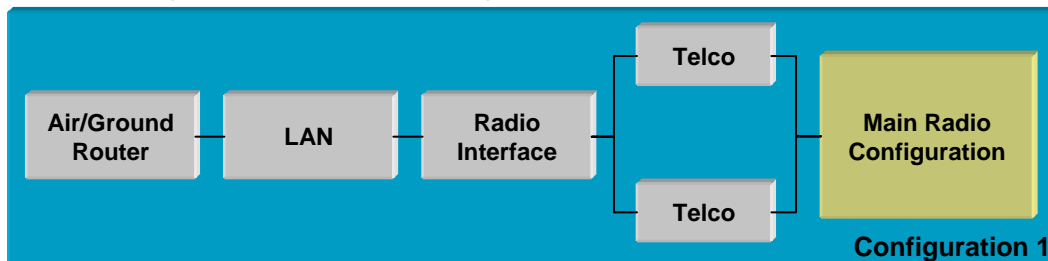
- Backup Radio Configuration
  - The backup radio contains a single series of components.
  - “NEXCOM Reliability, Maintainability, and Availability (RMA)” and “Next Generation Air/Ground Communications” documents were the main sources for configuration parameter values



Backup Radio Configuration

RMA Analysis	MTBF (hrs)	MTTR (hrs)	Availability
Radio Interface	40000	0.5	0.999987500
Main Tx	52560	0.5	0.99999049
Main Ant.	52560	0.5	0.99999049
Main Rx	52560	0.5	0.99999049
Prime Power	5662	0.5	0.9999117
<b>Backup Radio Configuration</b>			<b>0.999870666</b>

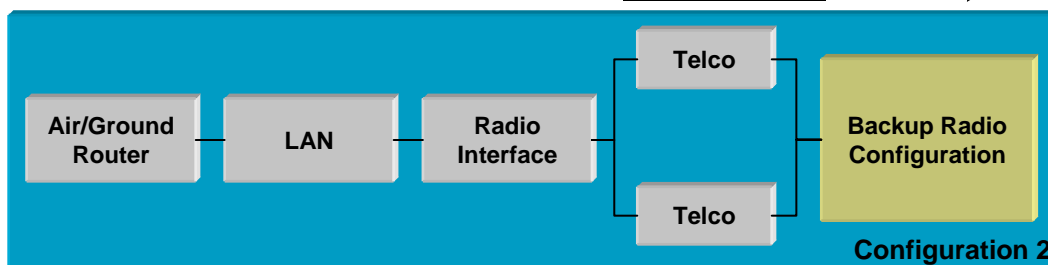
- Several potential architectures were examined in order to achieve availability values that closely meet availability requirements and maintain low cost.



#### RMA Analysis

	MTBF (hrs)	MTTR (hrs)	Availability
Air/Ground Router	60000	0.5	0.999991667
LAN	50000	0.5	0.999990000
Radio Interface	40000	0.5	0.999987500
Telco			0.997900000
Telco			0.997900000
Main Radio			0.999984425

**0.999949183**



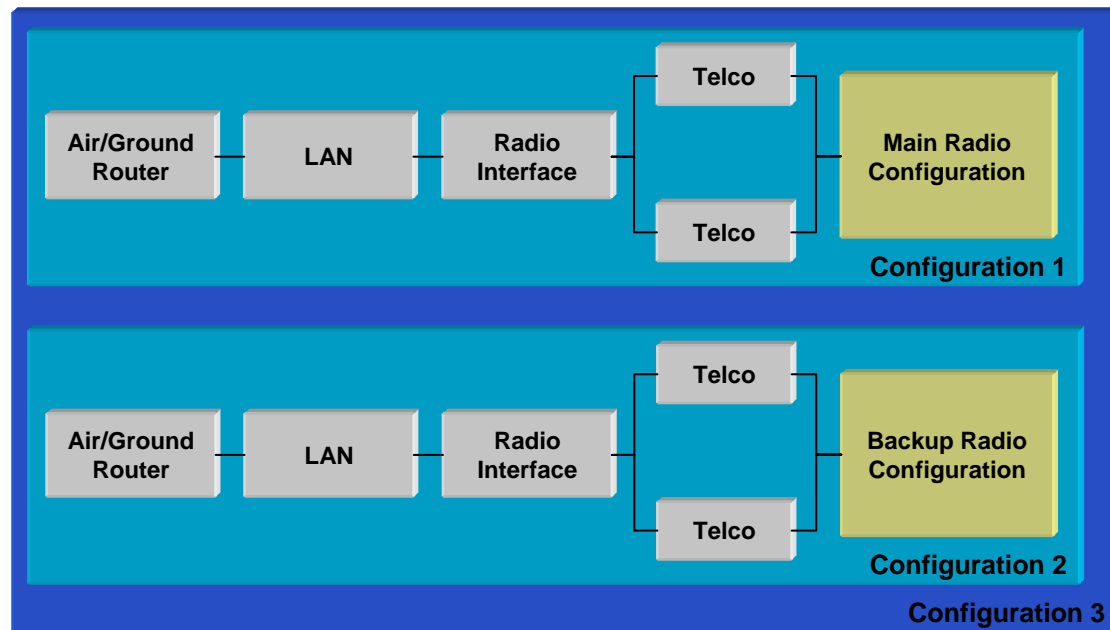
#### RMA Analysis

	MTBF (hrs)	MTTR (hrs)	Availability
Air/Ground Router	60000	0.5	0.999991667
LAN	50000	0.5	0.999990000
Radio Interface	40000	0.5	0.999987500
Telco			0.997900000
Telco			0.997900000
Backup Radio			0.999870666

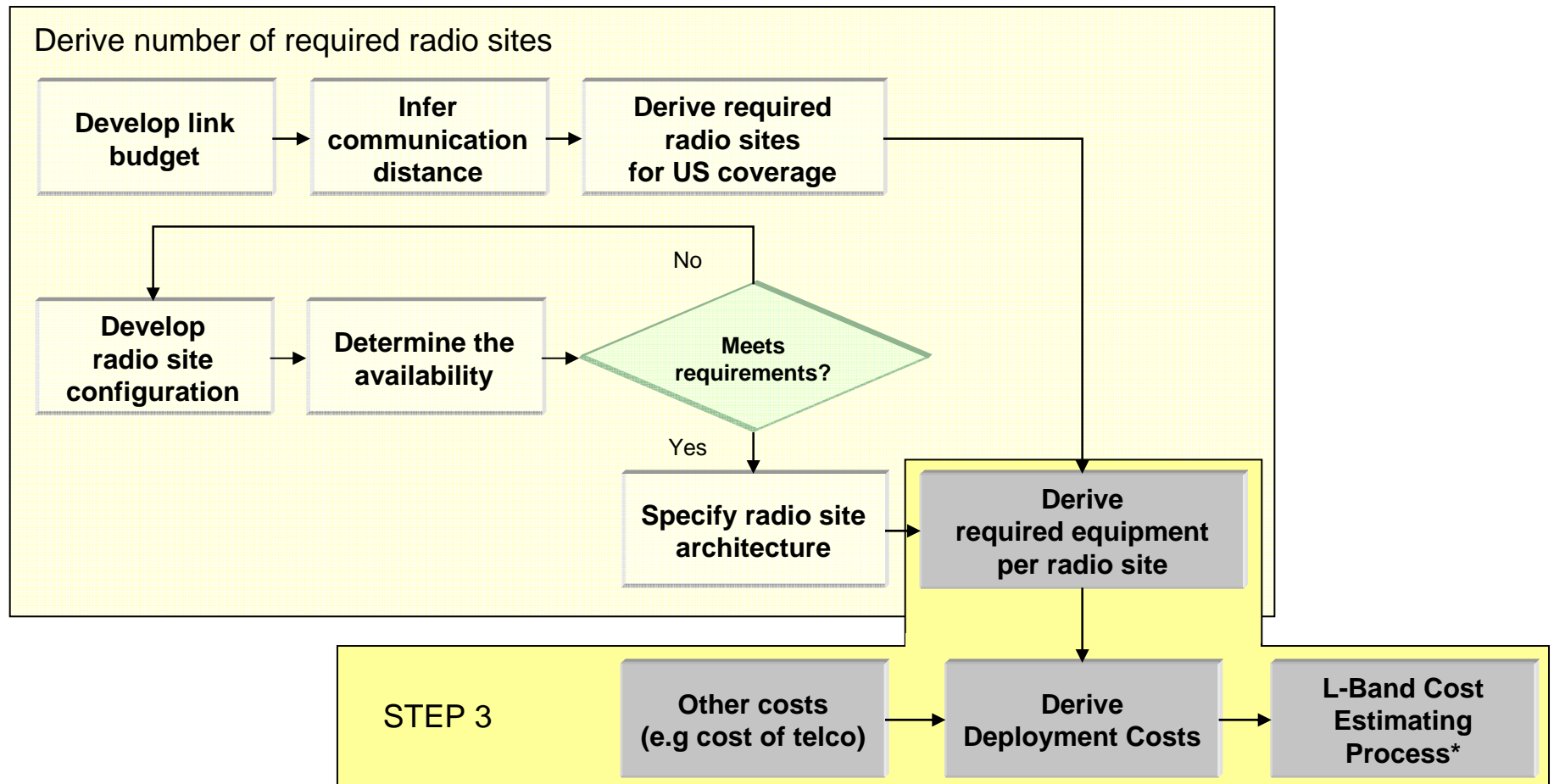
**0.999835428**

Telco's availability is the main driver of the overall availability. In a radio site architecture where only one Telco component is used the overall availability is always lower than the availability of the component with the lowest availability value (i.e. Telco 0.9979). A parallel Telco component is added in both Main and Backup radio site architecture, in order to improve availability. The price we pay is the cost of an additional leased telecommunication service (Telco).

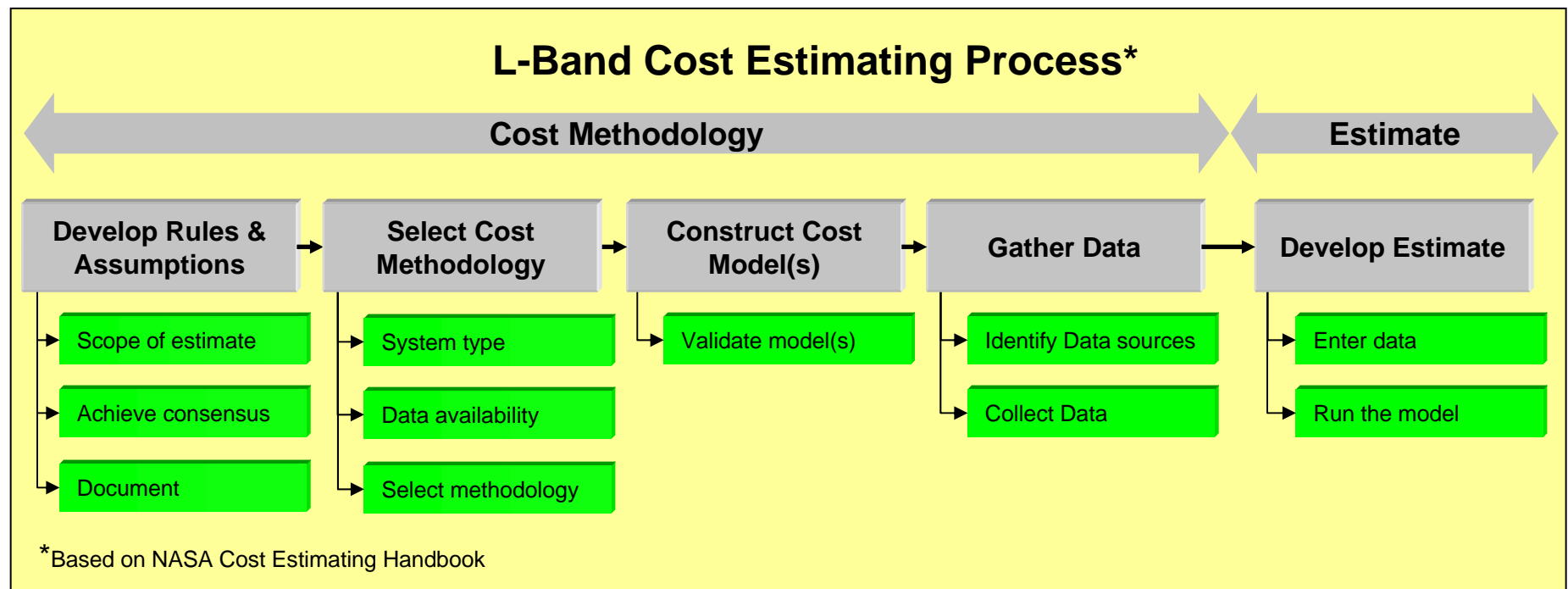
- To achieve the COCR Phase II En-route Ap requirements of 0.99999995 a parallel radio site architecture is needed. The architecture and RMA analysis are shown below
  - This architecture availability meets COCR requirements ( $1-8.0E-9 > 1-5.0E-8$ )
  - Use this radio site architecture to derive required equipment



RMA Analysis	
	Availability
Configuration 1	0.999949183
Configuration 2	0.999835428
	<b>0.999999992</b>



\* The L-Band cost estimating process is described in detail later in the presentation





# Cost Estimating – Develop Rules & Assumptions



## FAA LCC Model (all elements)

### **Research and Development**

- Feasibility Analysis
- Environmental Assessment
- Prototype Hardware
- Test Facilities
- Technical Experiments
- Operational Tests
- Construction Project Design and Engineering Plans
- Coordination with Regional Development and Transportation Plans
- System Design and Engineering
- R&D Oriented Software
- Modeling and Simulation
- Regulatory Analysis (prior to issuance of a final regulation)
- Arrangement of Project Financing
- Public Outreach

### **Investment**

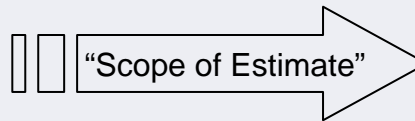
- Land
- Facilities
- Equipment
- Other regulatory implementation costs
- Transition costs.

### **Operations and Maintenance**

- Personnel Costs
- Consumables
- Energy and Utilities
- Facilities
- Telecommunications
- Computer Service Costs:
- Spares and Support Equipment
- Packaging, Handling, and Transportation
- Recurring Training
- Recurring Travel

### **Termination**

- Dismantling Costs
- Transportation and Packaging
- Site Restoration
- Storage of Material Management
- Salvage Value (offset to termination costs)



## FAA LCC Model Elements Selected for Analysis

### **Research and Development**

- System Design and Engineering
- Modeling and Simulation
- Other costs

### **Investment**

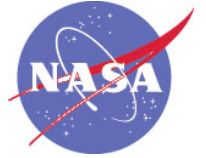
- Facilities
- Equipment
- Other regulatory implementation costs

### **Operations and Maintenance**

- Telecommunications
- Other costs



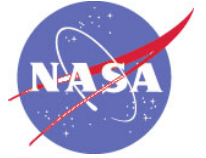
# *Cost Estimating – Develop Rules & Assumptions (2)*



- Assumptions
  - L-Band system provides coverage to United States, including Alaska and Hawaii
  - Coverage is above FL 180
  - System Availability of Provision meets COCR requirements for Phase II En-route services (sans Auto-Execute)
  - Cost elements considered are
    - Research and Development
      - System Design and Engineering
      - Modeling and Simulation
      - Other costs
    - Investment
      - Facilities
      - Equipment
      - Other regulatory implementation costs
    - Operations and Maintenance
      - Telecommunications
      - Other costs (personnel, etc.)



# *Cost Estimating - Select Methodology & Construct Model\**

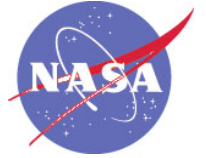


- Objective of the cost model is to evaluate the economic profitability and liquidity of the single proposed solution for the L-Band coverage.
- Measures of a project's profitability
  - Present Worth (PW)
  - Future Worth (FW)
  - Annual Worth (AW)
  - All measures are essentially equivalent; they differ in their time reference
- Measures of a project's liquidity
  - PW Simple Payback Method
  - FW Discounted Payback Method
  - AW Investment Balance
  - Each of these models provide the same "answer"; they differ in their frame of reference
- Select "PW Simple Payback Method" as the Methodology for Cost estimating model
  - This model compares current costs to discounted future returns (and discounted future costs)
  - "Answer" is in today's dollars

\* William G. Sullivan, James A. Bontadelli, Elin M. Wicks: "Engineering Economy," 11th Ed., 2000



## *Cost Estimating - Select Methodology & Construct Model (2)*



- There are several elements of the PW Simple Payback Model
  - Capital Investment
  - Annual Revenue
  - Annual Expenses
  - Minimum Attractive Rate Of Return
    - MARR is an interest rate used to convert cash flows into equivalent worth at some point in time
      - For the PW model, the “point of time” is the present
    - Usually an organizational policy issue based on:
      - amount, source and cost of money available for investment
      - amount of perceived risk of investment opportunities
      - estimated cost of administering projects over short and long run
      - type of organization involved
    - We will use MARR of 5% for initial L-Band cost model
      - Typical range of MARR is between 5 and 25 percent
      - We selected our value because the project is viewed as Low Risk with not too much initial investment required

- PW Simple Payback Method Model

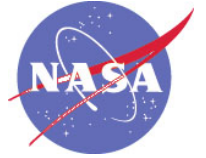
- Indicates liquidity (riskiness) rather than profitability
- Given the number of years, use this method to calculate the minimum annual revenue required for capital investment recovery
- The following inequality formula is used to find the  $AR_k$

$$\sum_{k=1}^4 (AR_k - AE_k) (P / F, i \%, k) - I \geq 0$$

- »  $AR_k$  is annual revenue in year k (this is the unknown)
- »  $AE_k$  is annual expenses in year k
- » I is the capital investment made at the present time
- » i is the interest rate equal to MARR
- » Required time 4 years



## *Cost Estimating – Gather Data*

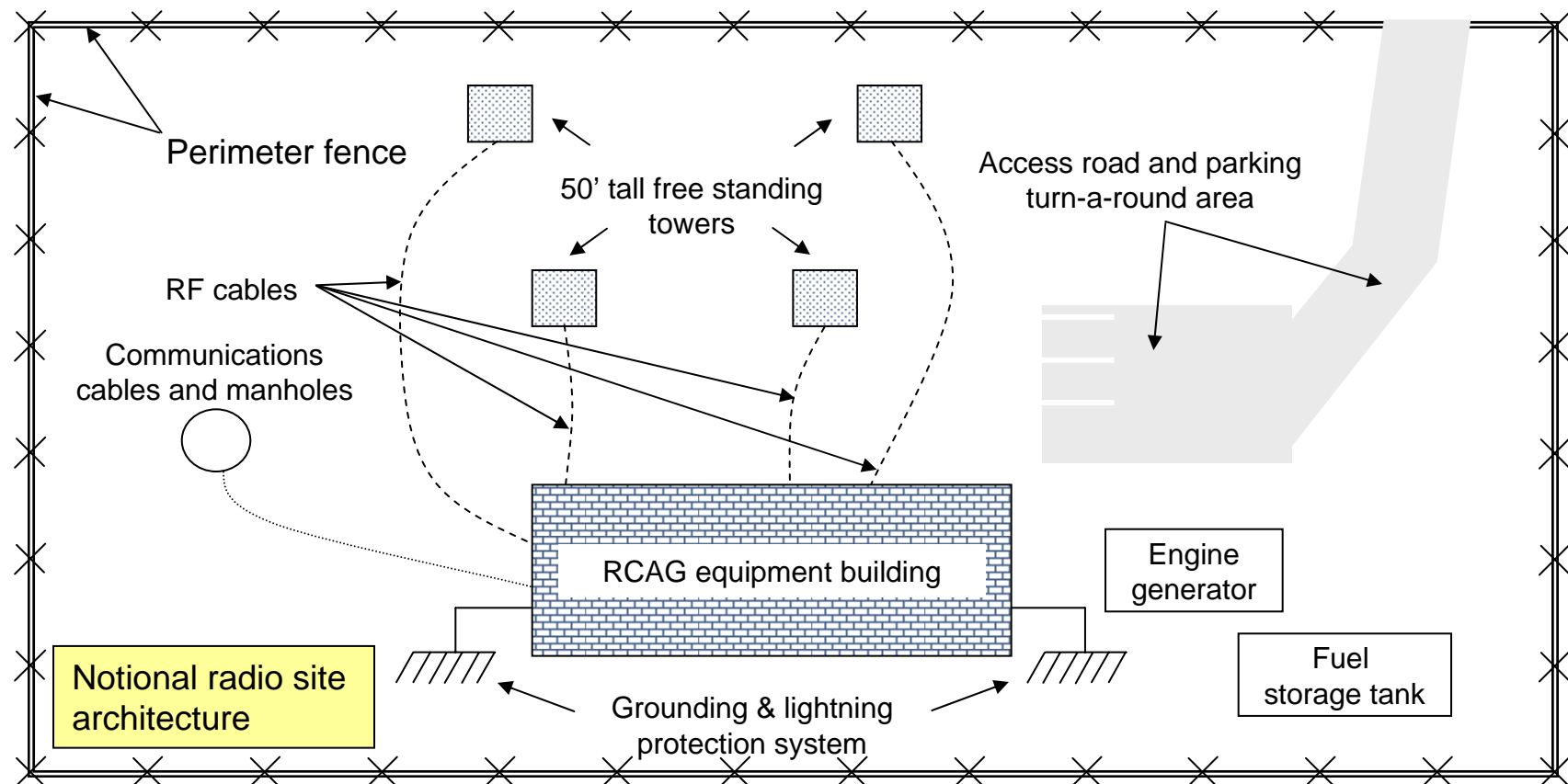


- We will develop an estimate for radio sites, by generating a manifest of typical radio site components by analogy to existing infrastructure. Construction costs will also be by analogy
  - Demarcation between construction and equipment costs is somewhat arbitrary
    - We have defined the following as the typical radio site components that would be provided by “site construction”. The next slide shows our typical site, and gives our basis of estimate for construction costs
      - Free standing steel antenna support towers (typically 50 -70 feet high, and typically four per site)
      - Equipment building (concrete masonry or pre-fabricated poured concrete)
      - Access road and parking turn-a-round area
      - Underground radio frequency (RF) and power cables
      - Grounding & lightning protection system
      - Perimeter fence
      - Engine generator
      - Fuel storage tank
    - Additional required equipment includes radios, antennas and Telco interface equipment. This is described on subsequent slides.

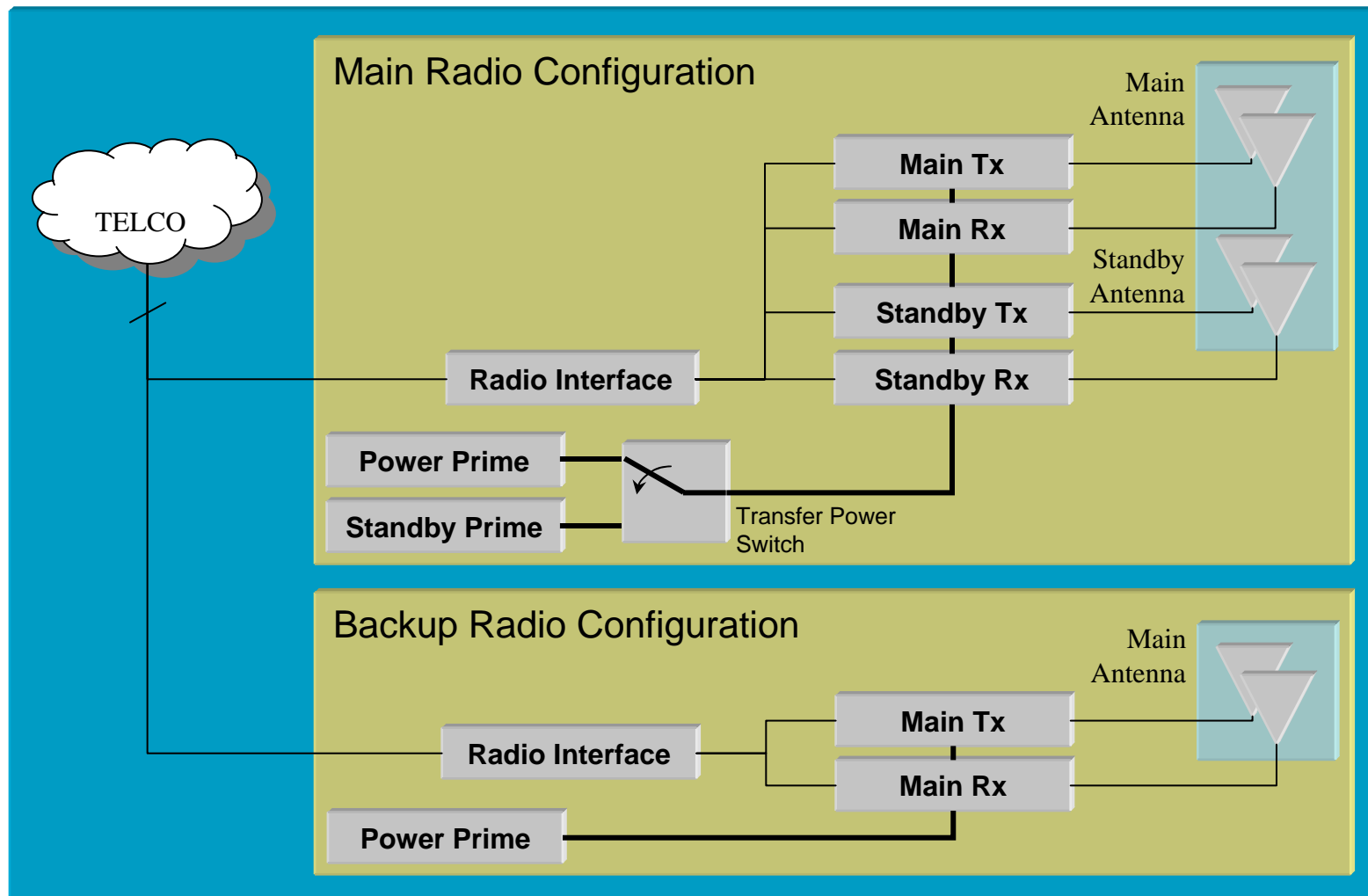
- Estimating construction costs

- Construction costs were estimated by searching FAA contract opportunities for contracts

- DTFA14-02-R-34237 synopsis cites FAA contract offer range \$500,000 to \$750,000 for Indianapolis Int. Airport RCAG site construction
    - Because of the location of this radio site (on an airport), the contract price is higher than the average. For our analysis, the average radio facility cost should be close to the low bound contract range. Select \$500,000 as the average facility construction cost.



Notional radio site equipment configuration used to develop equipment cost estimate





# Cost Estimating – Gather Data Equipment Cost (2)



- Estimated cost for radio equipments were taken from previous cost estimation work for VHF radio equipments. The estimated cost for L-Band receiver/transmitter (Rx/Tx) was considered to be twice the cost of a VHF Rx/Tx since, in the today's market, the selection of L-Band Rx/Tx is more limited.
  - Based on the “First Order Analysis of Required Bandwidth for the Next-Generation Aeronautical Data Link” paper, the radio site may need more than one frequency to meet data rate requirements. The increased number of required frequencies per radio site linearly increases the number of equipments such as Receivers, Transmitters, and Equipment Racks.
  - The average number of frequencies required per radio site is 2.29 for base rate of 100kbps

## Main Radio Cost

2.29

Item	Description	Estimated Cost	Quantity/Freq	Total Cost
Transmitter	L-Band Transmitter	\$10,000.00	2	\$45,800.00
Receiver	L-Band Receiver	\$10,000.00	2	\$45,800.00
Antenna	L-Band Antenna	\$2,832.00	4	\$25,941.12
UPS	Uninterruptible Power Supply	\$6,975.00	2	\$13,950.00
Radio Interface	Remote Radio Control Equipment	\$2,500.00	1	\$2,500.00
Cables and Connectors	Various	\$5,000.00	1	\$11,450.00
Equipment Rack	Equipment Racks	\$1,150.35	2	\$5,268.60
Transfer Power Switch	Automatic power switch transfer	\$1,500.00	1	\$1,500.00
32 kW Diesel Generator	Diesel Generator	\$9,200.00	1	\$9,200.00
				<b>\$161,409.72</b>

Includes multiplication by 2.29 to account for additional hardware due to the number of frequencies required

## Backup Radio Cost

Item	Description	Estimated Cost	Quantity/Freq	Total Cost
Transmitter	L-Band Transmitter	\$10,000.00	1	\$22,900.00
Receiver	L-Band Receiver	\$10,000.00	1	\$22,900.00
Antenna	L-Band Antenna	\$2,832.00	2	\$12,970.56
UPS	Uninterruptible Power Supply	\$6,975.00	1	\$6,975.00
Radio Interface	Remote Radio Control Equipment	\$2,500.00	1	\$2,500.00
Cables and Connectors	Various	\$5,000.00	1	\$11,450.00
Equipment Rack	Equipment Racks	\$1,150.35	1	\$1,150.35
Transfer Power Switch	Automatic power switch transfer	\$1,500.00	1	\$1,500.00
32 kW Diesel Generator	Diesel Generator	\$9,200.00	1	\$9,200.00
				<b>\$91,545.91</b>

Includes multiplication by 2.29 to account for additional hardware due to the number of frequencies required

Average equipment cost per radio site **\$126,477.82**



# Cost Estimating – Gather Data O&M Cost Source of Data (3)



- For O&M cost we used Safe Flight 21-CBA Basis of Estimates, April 2001 document to derive several O&M costs aspects for L-Band radio sites.
  - SF21 Basis of Estimates document provides among other estimates the ADS-B link NAS-Wide Enroute O&M Cost Detail. This costs are divided in 5 main cost elements
    - Site Maintenance
    - Program Support
    - Logistics
    - Second Level Engineering
    - Infrastructure Support (dominated by Leased Telecommunications costs)
- For the first four elements, it can be concluded that both ADS-B and L-Band radio sites incur similar O&M costs. This is because both systems perform similar functions, include comparable number of equipment in their inventories, and require similar staffing and maintenance to achieve system availability requirements.

L-Band O&M cost derivation				
	O&M ADS-B Total 28 years	O&M ADS-B Total/year	O&M ADS-B Total/year/radio site	O&M L-Band 132 radio sites Total/year
Total Site Maintenance (PM+CM)	\$16,726,900.00	\$597,389.29	\$5,973.89	\$788,554
Program Support	\$2,742,100.00	\$97,932.14	\$979.32	\$129,270
Logistics	\$28,996,500.00	\$1,035,589.29	\$10,355.89	\$1,366,978
Second Level Engineering	\$21,316,000.00	\$761,285.71	\$7,612.86	\$1,004,897
				<u>\$3,289,699.29</u>

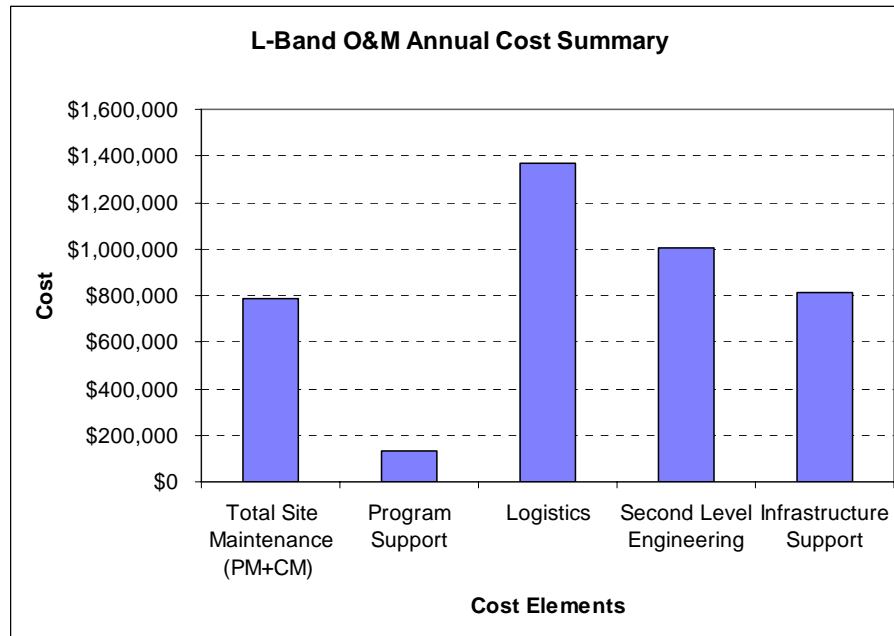




# Cost Estimating – Gather Data O&M Cost Derivation (5)



- Based on the previous map, most radio sites require only one DS0 line but only two radio sites (ID9, 77.3kbps and ID13, 56kbps) require two DS0 lines.
  - Main and backup radios because of telco redundancy require twice the number of DS0 lines. Following is the calculation used to derive the total number of DS0 lines for all radio sites



## L-Band O&M cost derivation

	<56kbps	>56kbps	Required redundancy	DSO lines
Main radios	64	2	2	136
Backup radios	64	2	2	136
Total DSO lines				272
DSO monthly charge				\$250.00

Leased Telecommunications yearly cost **\$816,000.00**



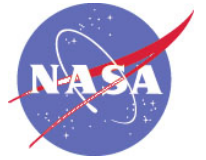
## L-Band O&M cost derivation

	O&M L-Band 132 radio sites Total/year
Total Site Maintenance (PM+CM)	\$788,554
Program Support	\$129,270
Logistics	\$1,366,978
Second Level Engineering	\$1,004,897
Leased Telecommunications	\$816,000.00

**\$4,105,699.29**



# *Cost Estimating – Develop Estimate*



- Initial Investment and O&M estimated costs summary

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## FAA LCC Model Elements

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<i>Research and Development</i>	<b>\$20,000,000.00</b>
System Design and Engineering	\$10,000,000.00
Modeling and Simulation	\$6,000,000.00
Other costs	\$4,000,000.00
<i>Investment</i>	<b>\$114,695,071.78</b>
Cost for all Radio Sites (equipment, construction, facilities)	\$82,695,071.78
Other Facilities (3 POP)	\$30,000,000.00
Other regulatory implementation costs	\$2,000,000.00
<b>Initial Investment</b>	<b>\$134,695,071.78</b>
<hr/>	
<i>Operations and Maintenance</i>	<b>\$4,105,699.29</b>
Telecommunications	\$816,000.00
Other costs	\$3,289,699.29
<b>O&amp;M</b>	<b>\$4,105,699.29</b>

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- Enter data and derive annual required revenue

## Inputs

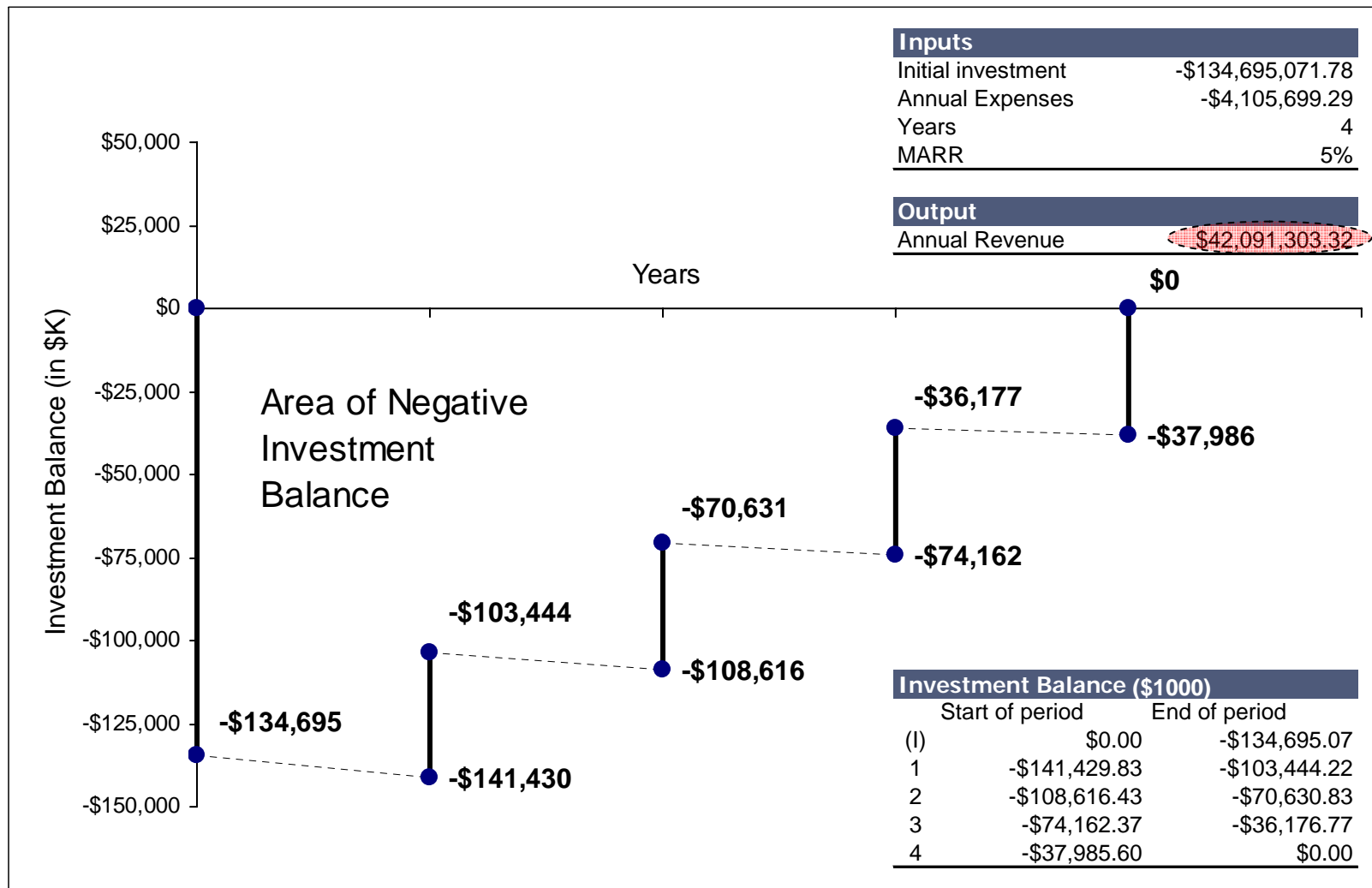
Initial investment	-\$134,695,071.78
Annual Expenses	-\$4,105,699.29
Years	4
MARR	5%

## Output

Annual Revenue	\$42,091,303.32
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## Investment Balance (\$1000)

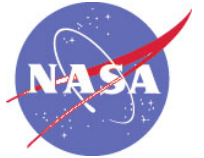
	Start of period	End of period
(I)	\$0.00	-\$134,695.07
1	-\$141,429.83	-\$103,444.22
2	-\$108,616.43	-\$70,630.83
3	-\$74,162.37	-\$36,176.77
4	-\$37,985.60	\$0.00





# *NASA Support for the Future Communications Study*

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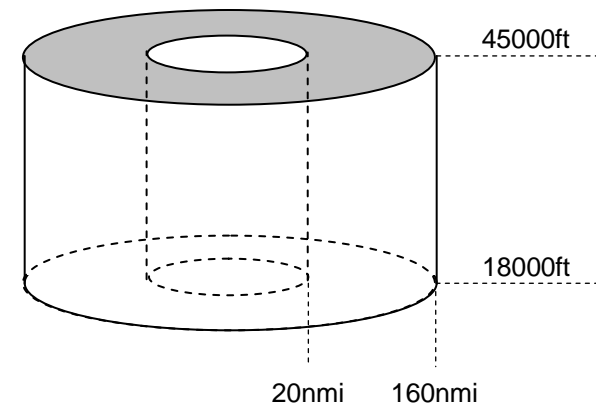
## *Supplemental – Derivation of Excess Path Loss*

- The objective is to derive a value for Excess Path Loss ( $L_{GR}$ ) to be used in our Link Budget calculation
  - Propagation Modeling Approach is to use the IF-77 Electromagnetic Wave Propagation Model (IF-77) developed by Gierhart & Johnson
  - Overall approach is to develop statistics for the excess path loss over a service volume, and select a reasonable value for  $L_{GR}$ , say  $\mu + 1.65\sigma$
- Analysis Flow
  - Define Service Volume for which we need to derive the  $L_{GR}$  statistics
  - Since the IF-77 model natively runs in a DOS shell, it was deemed expedient to develop a wrapper application to facilitate IF-77 model execution
    - Automate IF-77 model data generation and data collection procedure
  - Using the model, find  $L_{GR}$  values as function of distance, frequency, and altitude  $L_{GR}(\text{dist, freq, alt})$  with other parameters (e.g. facility antenna height, antenna pattern) held at fixed values
  - Calculate  $L_{GR}$  mean and variance for given service volume and frequency band

- Service Volume

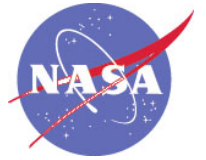
- Represents a typical airspace service volume that the communication radio will cover
- Modeled as a hollow\* cylinder with the following parameters
  - Height from ground (18000 ft)
  - Cylinder Height (45000 ft)
  - Inside radius (20 nmi)
  - Outside radius (160 nmi)
- Communication radio located 50 ft above ground at the axis of the service volume described above

\*It is understood that coverage is provided in the hollow center; however, the center was not modeled because the excess path loss is negligible.





## *Excess Path Loss Derivation - IF-77 Wrapper Application*



- IF-77 Electromagnetic Wave Propagation Model (Gierhart-Johnson) can be downloaded from U.S. Department of Commerce NTIA/IT Institute for Telecommunication Sciences website <http://flattop.its.bldrdoc.gov/if77.html>
- The following files are available from this ITS web site:
  - [ata.exe](#) An executable file for ATA. Runs on a PC under DOS. (changed 8 Sep 2000)
  - [atoa.in](#) Sample input file for ATA. Run with: `ata < atoa.in > atoa.out`
  - [atoa.out](#) Sample output file for ATA.
  - [cards.txt](#) Text description of data input cards.
- IF-77 wrapper application runs the `ata.exe` executable.
- IF-77 wrapper application was validated using the `atoa.in` and `atoa.out` files.



- IF-77 Electromagnetic Wave Propagation Model**

### IF-77 units

Units	ft/nautical miles
Output Type	Transmission Loss
Aircraft altitude units	Same as Units
Lobing options	No lobing
Time availability	Instantaneous levels
# of elev in label	
Label	VOR
Maximum distance	260
Output	distance
DMAX	no interpolation

### Facility

Antenna altitude	50
Antenna pattern	Isotropic
Antenna	directive
Antenna polarization	Vertical
Antenna tilt	
Antenna width	
Elevation	0
Rainfall Zones	No consideration
Site ed terrain	
Terrain type	Irregular terrain
Horizon	None specified
Terrain parameter	80
Distance to radio horizon	
Elevation of radio horizon above MSL	
Radio horizon angle in degrees	
Radio horizon angle in minutes	
Radio horizon angle in seconds	
Diameter of facility (ft.)	52
Height of facility	12
Code for counterpoise reflection	7

### Aircraft

Antenna altitude	45000
Antenna pattern	Isotropic
Antenna	directive
Antenna polarization	Vertical
Antenna tilt	
Antenna width	
Surface refractivity	301 N-units
Frequency (Mhz)	1024
EIRP (dBW)	0.0
Elevation of reflection surface	0
Earth reflection material	average ground
Temperature in Celsius	
Sigma in feet or meter	
Code for sea state	
Code for signal	use standard
Code for ionospheric Scintillation	
Code for frequency scaling	
Scintillation	no scintillation
Climate 1	Continental all years
Mixing	no mixing
Climate 2	Continental all years
Weighting for climate 2 when mixing	0

### Free Space

Attenuation vs Distance graph. Y-axis: Attenuation (dBm). X-axis: Distance (nmi).

Key points:

  - 0.00 nmi, 1.16 dBm
  - 58.06 nmi, -0.00 dBm
  - 58.06 nmi, -1.16 dBm

### Plot Excess Path Loss 95%

Data Collection

Stop

44

154.91      2.40

```

AABBCDDDEFFFGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGHHHHHIIJJ
3 2 0 0 2 2IVOR                                     260 0 0
3 3 0 0 2 2IVOR                                     260 0 0
AAAAAABBBCCDDEEEEEFFFFFGGGGHIIIJJKLLLLLLMMMMNNNNNOOPPPQRRRRSSSSSTTTT
    16 4 0 1          0 0 1 0                      52 12 7
    50 1 0 2          0 0 2 0 80                    52 12 7
AAAAAABBBCCDDEEEEEFFFFFGGGGHIIIJJKLLLLLLMMMMNNNNNOOPPPQRRRSSTTTTUUVVVV
30000 1 0 1          301 113 22.2 0 3              0 0 0
45000 1 0 2          301 1024 0.0 0 3               0 0 0

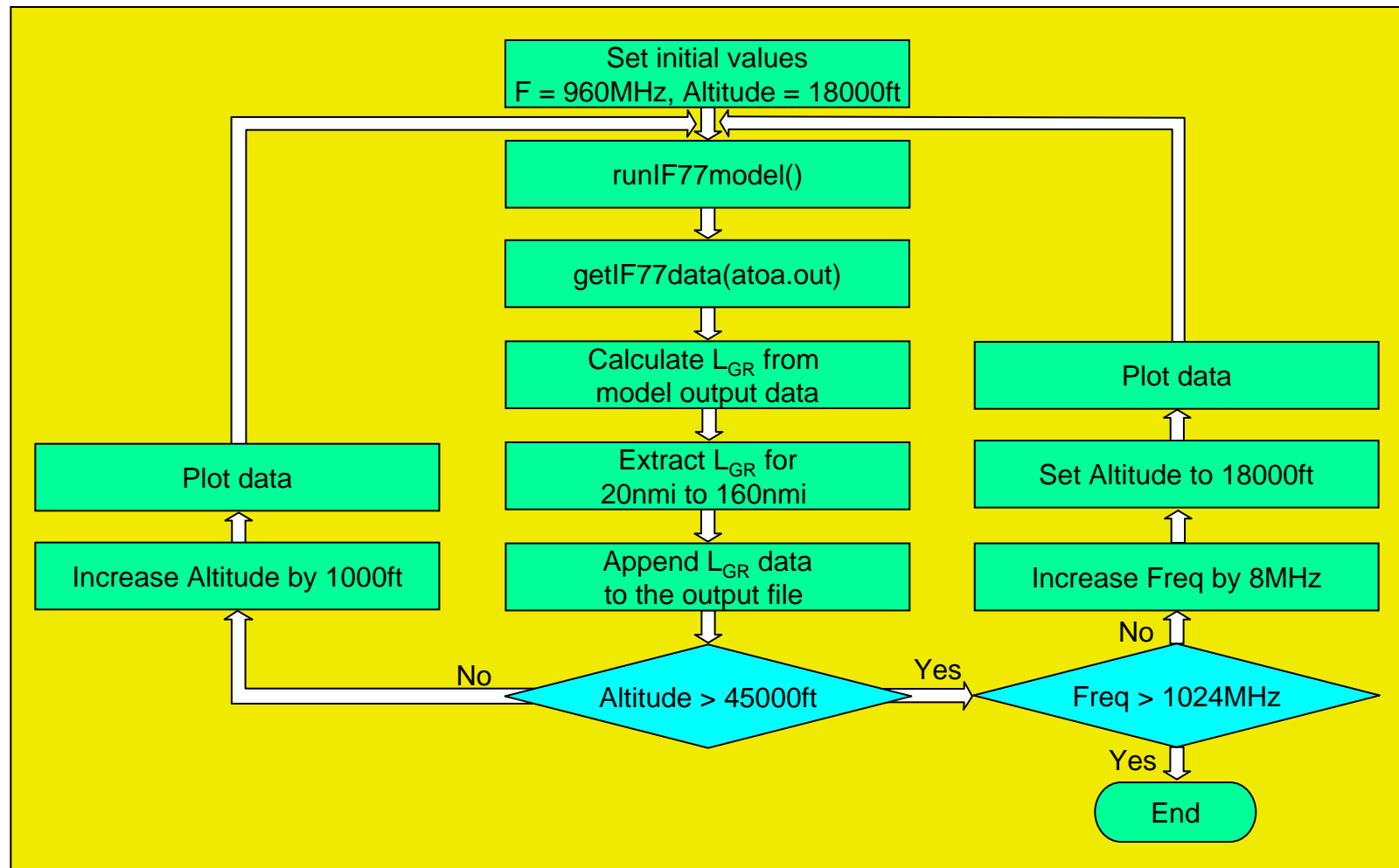
```

Run IF-77 model

Create input file

Quit

- Automation program flow for generating  $L_{GR}$  model data



- Used terrain parameter of 80 slightly rolling plains for Excess Path Loss ( $L_{GR}$ ) statistics derivation

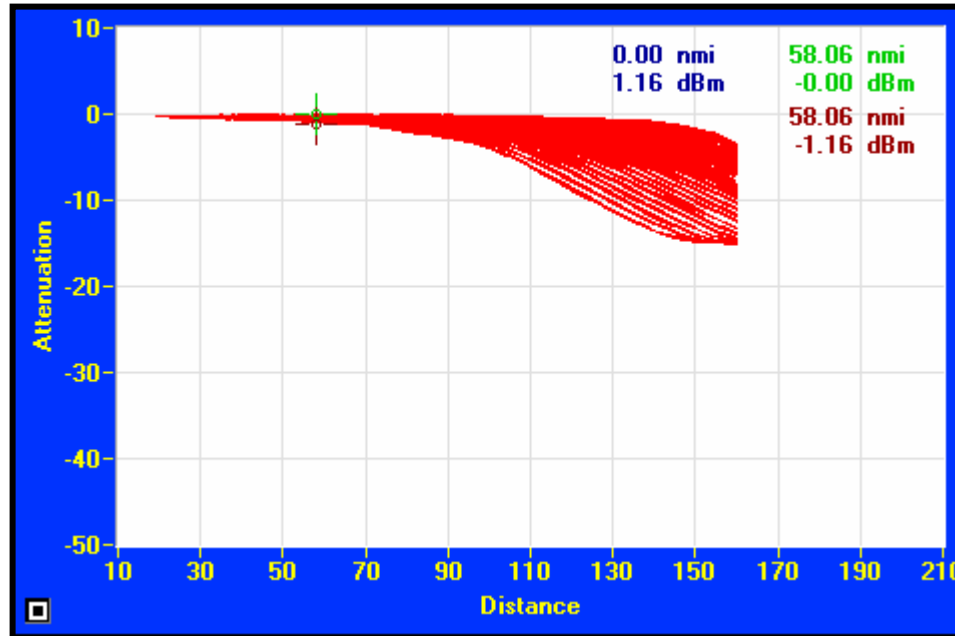
Facility	
Antenna altitude	50
Antenna pattern	Isotropic
Antenna	directive
Antenna polarization	Vertical
Antenna tilt	
Antenna width	
Elevation	0
Rainfall Zones	No consideration
Site elevation	
Terrain type	Irregular terrain
Horizon	None specified
Terrain parameter	80
Distance to radio horizon	
Elevation of radio horizon above MSL	
Radio horizon angle in degrees	
Radio horizon angle in minutes	
Radio horizon angle in seconds	
Diameter of facility (ft.)	52
Height of facility	12
Code for counterpoise reflection	7

## Terrain parameter in feet\*

Water or very smooth plains	0-20
Smooth plains	20-70
Slightly rolling plains	70-130
Rolling plains	130-260
Hills	260-490
Mountains	490-980
Rugged Mountains	490-980
Extremely rugged mountains	>2000

\*Johnson M.E., Gierhart G.D. Applications Guide for Propagation and Interference Analysis Computer Programs (0.1 to 20 GHz) March 1978: 101

- Plots of  $L_{GR}$ (distance, frequency, altitude) data



- Irregular terrain (Slightly rolling plains 160nmi / 200nmi)
  - For the service volume under consideration ~16,000  $L_{GR}$  data were collected
  - Mean  $L_{GR}$  = -2.22dB / -4.92dB.
  - Use -4.00dB for link budget calculations (Wilson, Warren J. email 1/27/2006)
  - Standard Deviation  $L_{GR}$  = 3.33dB / 5.99dB